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LASER ILLUMINATED ETCHED TRACK SCATTERING (LITES) DOSIMETRY SYSTEM

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Abstract — Los Alamos National Labs (LANL) has developed an etched track foil (CR-39) reader for neutron dose between 0 and 50.0 mSv. Currently, the US Department of Energy mandates general employee annual exposure not to exceed 50.0 mSv (5 rem). At LANL, due to a non-linear response at higher exposures, accepted practice only uses an Autoscan 60 system up to 3 mSv. The LITES system, however, has demonstrated linear response to 50 mSv, where the proprietary design measures the amount of laser light scattered by the etched tracks, proportional to dose. A collection of calibrated foils was counted by an Autoscan 60 and the LITES prototype, and the Autoscan 60 showed good linearity when counting exposure up to about 15 mSv, but not for higher exposures. From 0 to 50 mSv, the Autoscan 60 had a correlation coefficient of $R^2 = 0.941$ and the LITES system had $R^2 = 0.991$.

PROBLEM IDENTIFICATION AND SOLUTION

In the United States, the current regulatory environment and budgetary stewardship concerns are both motivating factors for the development of automated procedures for volume processing of personal dosemeters. Currently, the US Department of Energy mandates general employee annual exposure not to exceed 50.0 mSv (5 rem)[1]. This paper describes an instrument designed to satisfy the US Department of Energy Laboratory Accreditation Program[2,3] (DOELAP) for Personnel Dosimetry requirements for neutron dosimetry. Two devices capable of automated reading of etched track CR-39 foils were recently developed and tested at the Los Alamos National Laboratory and the Georgia Institute of Technology. (The instrument at Georgia Tech is a complementary design *vis-à-vis* the Los Alamos system; the details of this work will be described in a future publication.) These two new instruments are based upon a concept in etched track dosimetry that was developed at Los Alamos National Labs by one of the authors (R.E.H.). The DOELAP requirements for neutron personal dosimetry call for a procedure to accurately evaluate dosemeters which have been exposed to neutron dose equivalents to 5.0 rem (50.0 mSv). (Author's note: Although the DOE documents specify dose equivalent in terms of 'rem', this paper will refer to dose equivalent in SI units hereafter.) A patent application pertaining to the new technology has been submitted to the US Patent Office for approval and accepted.

PAST RESEARCH AND LITERATURE REVIEW

Other researchers in the past have measured light scattered through etched track dosemeters. Tuyn[4] demonstrated an almost linear relation between transmitted light and track density for phosphate glass irradiated with fission fragments. Schultz[5] used a mercury light source to measure scattered light from fission tracks in glass and Lexan plastic. Scattered light intensity was measured in amperes (in a photomultiplier tube) and related to the time of exposure of the dosemeters in a thermal neutron field. Khan[6] used a non-coherent light source to measure etched track density created by fission fragments and alpha particles in Lexan plastic (etched by KOH). Another brief study by Platzer *et al*[7] used coherent light from a He–Ne laser to scatter light from etched tracks in cellulose nitrate foils. The relative intensity of scattered light was measured in relation to the irradiation time in an alpha particle field. El Hofy and Elsamman[8] studied the relation between optical track density, alpha energy and etching time.

More recently, relationships were developed showing the linearity between the intensity of transmitted light through etched track dosemeters and neutron kerma (Bordy *et al*[9]) and fission fragment track density (Gold and Roberts[10]).

Much important work has been done by the Université de Franche-Comté[11–13]. In this collection of studies, a method of evaluating etched tracks in CR-39 was developed using the previously demonstrated principle of light scattering. Additionally, a computational method was developed for predicting the amount of scattered light based on track density, size and orientation. Good agreement has been shown in this work between computed and experimental results for the amount of scattered light as a function of the scattering angle.

NEW LOS ALAMOS AND GEORGIA TECH PROTOTYPES

The current instrument under development at Los

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Alamos National Labs has been designed to meet the US DOELAP requirements for measuring neutron dose equivalent with CR-39 etched track dosemeters. This laser illuminated track etch scattering (LITES) device is similar to other light scattering systems used in the past, but a patent of the LITES design has been filed and accepted by the US Patent Office in regard to unique characteristics of this approach. A key portion of the system is indicated in the schematic (Figure 1), where a beam stop prevents the full power laser light from impinging on the photodetector surface. Other researchers in the past avoided the full power beam as well, but usually by locating the detector at an off-axis location.

An additional feature of the LITES system is the focusing lens located downrange of the CR-39 foil, wherein scattered light which otherwise would escape measurement by the photodetector is refocused to increase sensitivity of the system. This refocusing lens therefore performs an averaging function over the solid angle subtended by the lens. The LANL LITES instrument includes a beam splitter and a second photometer to monitor laser power output fluctuations. Studies indicated this to be unnecessary in the Georgia Tech device.

EXPERIMENTAL RESULTS AND DISCUSSION

Four sets of CR-39 etched track foils are examined. Two sets of TASTRAK CR-39 foils ($20 \times 25 \times 1.5$ mm^3) were irradiated to dose equivalents of 1.0, 2.5, 5.0, 7.5, 10, 15, 20, 30, 40, and 50 mSv at Pacific Northwest National Lab (PNNL) in a bare ^{252}Cf neutron field and in a D_2O moderated ^{252}Cf neutron field. These foils are designated in this paper as 'GA Tech' foils. The other two foil sets were irradiated to dose equivalents of 2.0, 3.0, 5.0, 10, 20, 30 and 50 mSv at Los Alamos National Labs in a bare ^{252}Cf neutron field and in a D_2O moderated ^{252}Cf neutron field. These foils are designated as the 'LANL' foil set. Following irradiation, all of the foil sets were chemically etched at Los Alamos; the GA Tech foils were processed in one etch batch and the LANL foils in another. The etch protocol began with a 1 h pre-etch in a 60% methanol and 40% 6.25 N NaOH solution at 70ºC to remove alpha and heavy charged particle tracks. This was followed by a 15 h etch in 6.25 N NaOH maintained at 70ºC during the etch cycle. A 10 min stop etch using room temperature 0.1 N HCl and a final rinse with distilled water and a wetting agent completed the protocol. The etch protocol resulted in an average track diameter of 20 μm for bare ^{252}Cf tracks.

The LANL foil sets were analysed in the Los Alamos LITES system, and the GA Tech foils were done using the GA Tech LITES instrument. Since the two instruments are constructed differently the presentation of the experimental results reflect these distinctions. Figure 2 shows the two GA Tech foil sets on a plot of dose equivalent (mSv) against the measured amount of scattered light (W.cm^{-2}). Figure 3 shows the two LANL foil sets on a plot in terms of dose equivalent (mSv) against the non-adjusted light ratio, which is the measured ratio of scattered laser light to the reference laser light intensity after deflection by the system beam splitter. Both instruments demonstrated a linear relationship between the measured amount of scattered light and the known dose equivalent from the respective neutron source calibration facilities, with measured correlation coefficients greater than 0.99 being noted. At present, insufficient

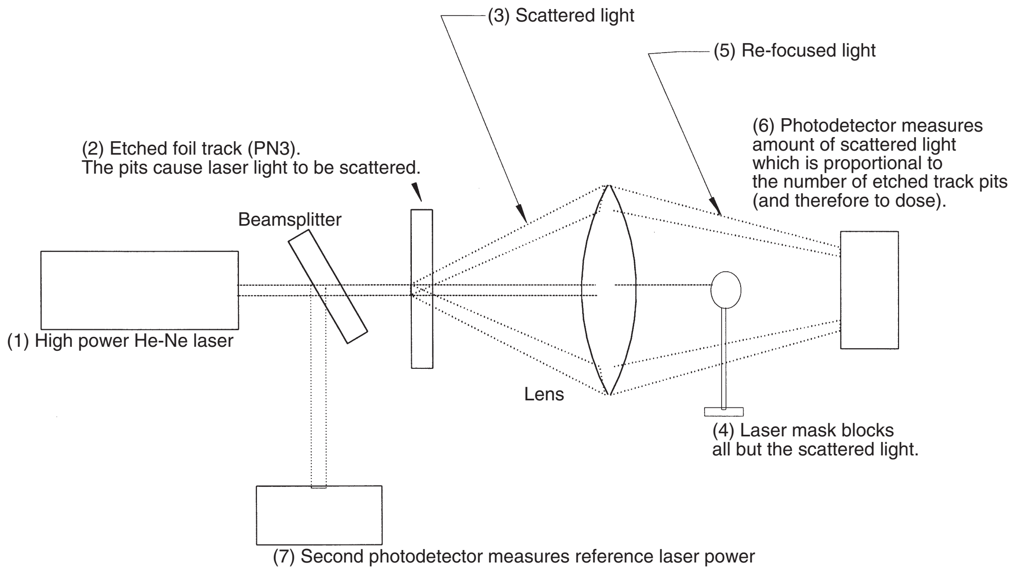

Figure 1. Schematic of laser illuminated etched track scattering (LITES) dosimetry system.

data exist for a reliable determination of the lower limit of detection (LLD) or the performance of the measurement technique (as described in the US DOE handbook[(3)]), but these tasks will be performed in preparation for the forthcoming DOELAP certification procedure in September 2001.

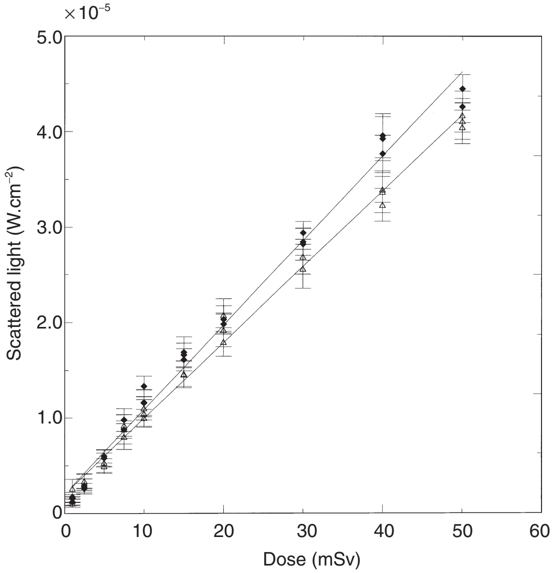

Figure 2. Foils from Georgia Tech analysed in the GA Tech LITES system. (△) Bare ^{252}Cf GA Tech, $R^2 = 0.994$, $y = 7.953 \times 10^{-7}x + 1.986 \times 10^{-6}$, (◆) Moderated ^{252}Cf GA Tech, $R^2 = 0.990$, $y = 8.866 \times 10^{-7}x + 1.980 \times 10^{-6}$.

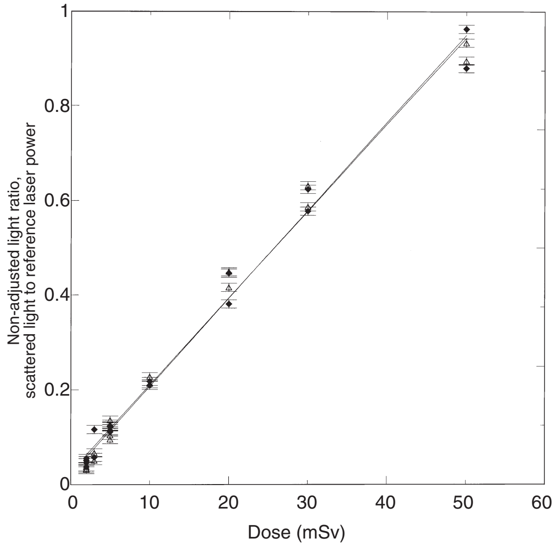

Figure 3. Foils from Los Alamos analysed in the LANL LITES system. (△) Bare ^{252}Cf LANL, $R^2 = 0.991$, $y = 0.0186x + 0.021$, (◆) Moderated ^{252}Cf LANL, $R^2 = 0.991$, $y = 0.0183x + 0.0264$.

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